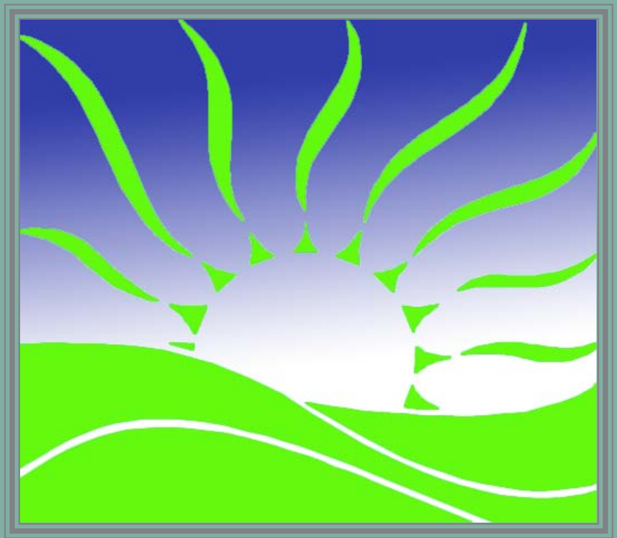
Cool Houston!

A Plan for Cooling the Region



For Clean Air & Quality of Life Benefits

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NOTE: The terms *albedo* and *solar reflectance* are used interchangeably in this report. Albedo is expressed in values from 0 to 1 while solar reflectance is expressed as a percentage from 0% to 100%. An albedo of .25 is equal to a solar reflectance of 25%.

Executive Summary

Cool Houston Plan

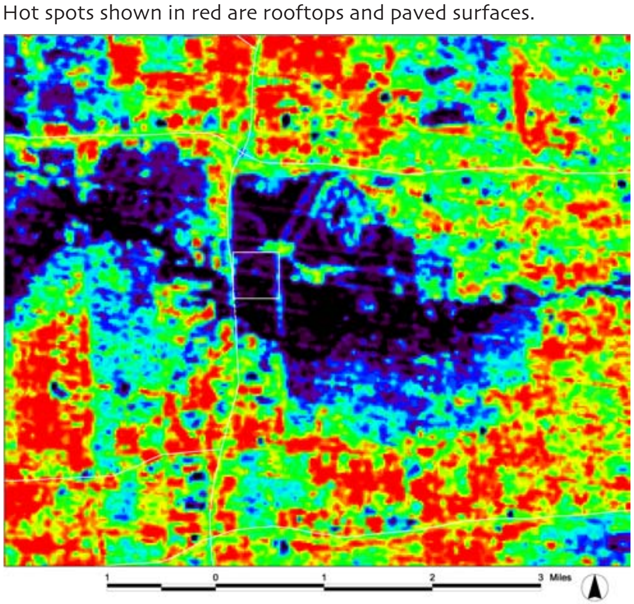
Houston is a hot place to be in the summer, but as the region grows, we've added another 6º to 8º on top. This phenomenon, known as the *urban heat island effect*, is caused by the use of dark roofing materials and dark pavements along with the extensive removal of trees and vegetation. Trees provide a complex, natural cooling process while dark materials used on rooftops and paving act as solar energy collectors, absorbing and retaining the sun's heat. Surface temperatures on rooftops reach 160º F or hotter, in turn heating the surrounding air.

The Cool Houston Plan sets forth actions that will literally change the surface of the region. While this would appear to be a daunting task, experience and research over the past 10 years has helped define how to make this happen.

Hotter temperatures have many negative effects, including poor air quality and a diminished quality of life. The list of specific problems from this added heat include higher ozone levels, higher electric bills, and heat related illnesses and death.

With currently available and affordable technologies, these effects can be reversed. Use of these technologies also provides a score of other benefits that are discussed in this document. Technologies include various reflective and porous paving products, reflective and green roofs, and one of the oldest technologies available – trees and vegetation.

Thermal image of Memorial Park and surrounding community.
Hot spots shown in red are rooftops and paved surfaces.

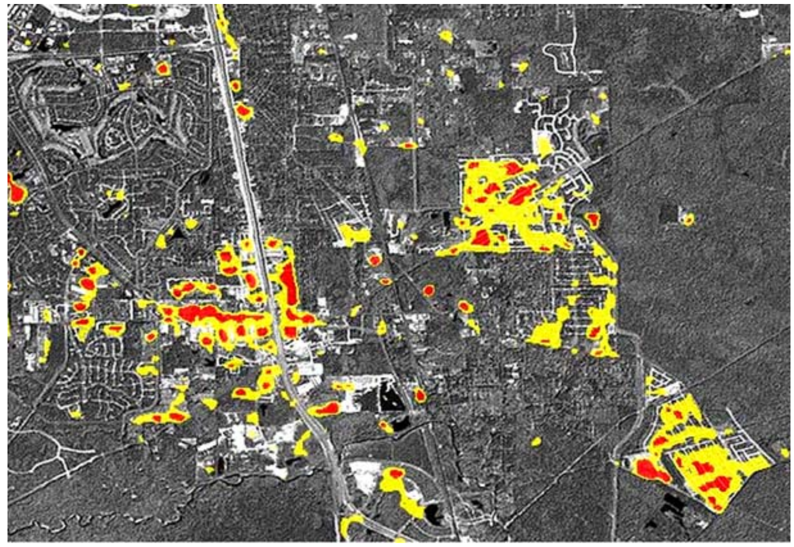


Making It Happen

The ***Cool Houston Plan*** *sets forth actions that will literally change the surface of the region.* While this would appear to be a daunting task, experience and research over the past 10 years has helped define how to make this happen. First, the Plan recognizes that many rooftop and paving surfaces are replaced or resurfaced every year; and that there are specific decision points when the new surface is selected. The Plan targets these decision points and the people likely to make these decisions. Second, the Plan targets those surfaces most likely to change, rather than all surfaces. Residential streets and driveways, for example, are rarely resurfaced. Parking lots, however, are resurfaced or coated fairly often. Building owners and managers generally make these decisions with input from contractors. These decisions can be affected by (1) incentives, (2) regulations, and/or (3) new information.

Third, the Plan proposes actions that are economically justified and that provide an additional stream of benefits to the property owner and community. Whether it is new trees or a new roof, the cool technologies in this report are affordable and provide multiple benefits. Trees, for example, not only cool the region, but improve property values, lower air conditioning costs, reduce stress, and help prevent flooding. While this sounds like a paid commercial for a miracle product, trees indeed provide a miraculous set of benefits and services for us.

Photo courtesy of Stephen Stetson, Global Environmental Management



Thermal image of development south of The Woodlands, Texas. Hot spots on the left of the photo are primarily commercial developments. On the right are residential developments where tree cover was greatly reduced in the early 1990s prior to development. Thermal data from year 2000 satellite information.

Goals

Within ten years in the 8-county Houston region, the following goals would be accomplished:

Cool Paving
The widespread use of cool paving technologies for new and existing parking areas, new local and neighborhood streets, and for maintenance resurfacing.

Cool Roofing
The widespread use of cool roofing on all flat roofs.

Cool Trees
Ten million new trees in ten years, coupled with greatly improved conservation activities.

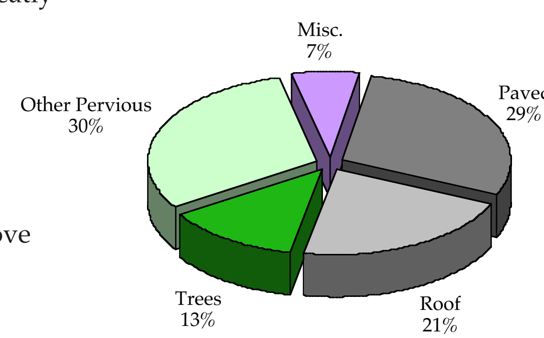
Air Quality
Inclusion of heat island measures in the Houston-Galveston-Brazoria State Implementation Plan.

Quality of Life
Improved quality of life through actions that improve flooding conditions, aesthetic qualities, human wellbeing and natural habitat.

Water
Improved water quality and management through application of heat island technologies.

Developed Land in Houston by Percent of Surface

About half of all developed land in Houston is either paved or roof tops. While more than 30% of the region is forested, in developed areas only 13% is trees. Another 30% is pervious surfaces such as grass or barren land.



Cool Roofing

A Component of the Cool Houston Plan

Introduction

The surfaces of traditional roof systems (i.e. built-up roofs, modified bitumen, etc.) can reach temperatures of 150º F to 180º F during summer months in the Houston area. These elevated temperatures can have many adverse effects for building owners, the roof itself, and the region where they are located. These effects can include:

- Increased energy use for cooling purposes resulting in higher utility bills.
- Increased use of HVAC (heating, ventilation, and air conditioning) equipment, possibly reducing its service life.
- Increased and/or more frequent maintenance of HVAC equipment due to continued use.
- Higher peak demand for electricity.
- Increased air pollution due to higher levels of electricity production.
- Accelerated deterioration of the roof membrane due to continued exposure to elevated temperatures.
- Increased roof maintenance due to accelerated aging of the roof membrane from exposure to elevated temperatures.
- Additional waste sent to landfills due to premature deterioration and subsequent replacement of roofing materials.
- Uncomfortable working environments for building occupants.

The elevated temperatures and resulting effects can be alleviated with the implementation of alternate roof systems that are referred to in this report as *cool roofs* or *cool roofing*. Many studies have shown that a cool roofs can reduce rooftop temperatures by 50º to 60º F during peak summer months. Although the materials utilized to achieve a cool roof have been promoted recently for this particular benefit, the technologies of most of these products have been in place for many years with positive and proven track records. Many commercial buildings in the Houston region have utilized cool roofing for years because of its energy benefits.

Long Range Cool Roofing Goal

The primary cool roofing goal is to achieve the widespread use of cool roofing in the Houston region over the next 10 years, focusing first on flat/low slope roofs.

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Roofing in the Houston Region

Roofing accounts for an estimated 21% of Houston's urban area.[10] As shown in Table 7, more than half of this roofing is residential. There are over 1.7 million housing units in the Houston region with roughly 3 to 4 billion square feet of roofing. The remaining roofing includes commercial, office, industrial and public buildings.

No comprehensive study of roofing types has been conducted for the Houston region. However, those in the roofing industry generally characterize roofing as (1) asphalt shingles for most single family residential units (70% or more), and (2) a split for commercial, office and other buildings among three major roofing materials: modified bitumen, built-up roofing (BUR) and single-ply roofing. These three types of roofing account for 80% or more of materials used on non-residential roofing surfaces.[11]

Reroofing of low slope roofs is a much larger part of the roofing industry's activities than new construction. Reroofing consists primarily of commerical and industrial applications. The roofing industry is split between residential and commercial with commercial roofing being a much larger portion of the market share (25% residential and 75% commercial).[12]

[10] S.L. Rose, H. Akbari, and H. Taha, 2003.
[11] National Roofing Contractors Association 2001-2002 Annual Market Survey.
[12] ibid.

Thermal image of buildings and surrounding development. The large roof top has the highest temperature.

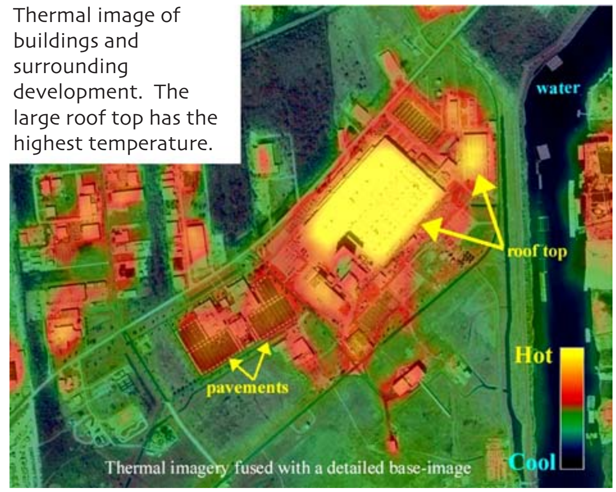


Image courtesy of Stephen Stetson, Global Environmental Management

Cool Roofing Technologies[13]

There are two basic roofing technologies that are available to achieve a *cool roof:* 1) surfacing with a *reflective roofing* product or 2) *green roofs/garden roofs*. There is a wide range of commercially available roof materials produced by

[13] For information on *cool roofs*, see the California Energy Commission website at http://www.consumerenergycenter.org/coolroof

For information on *green roofs* see:
http://hortweb.cas.psu.edu/research/greenroofcenter/index.html
http://www.greenroofs.com
http://www.greenroofs.ca/grhcc

Table 6
Land Use and Land Cover for the Houston Area*
in Square Miles

Land Use	Paved Surfaces	Roof	Tree Cover	Other Pervious Surfaces	Misc.	Total	Percent
Residential	183.4	152.7	125.3	250.4	31.8	743.6	56.1%
Commercial/Service	30.1	19.7	4.7	9.3	3.7	67.6	5.1%
Industrial	30.7	18.9	8.6	51.6	13.5	123.2	9.3%
Transportation/ Communications	19.8	4.0	0.3	5.4	8.9	38.4	2.9%
Industrial and Commercial	20.3	16.8	4.7	15.7	6.1	63.7	4.8%
Mixed Urban or Built-Up Land	16.2	11.6	3.7	11.5	3.5	46.4	3.5%
Other Mixed Urban or Built-Up Land	84.5	60.5	19.1	60.0	18.4	242.5	18.3%
Total Square Miles	385.0	284.2	166.4	403.9	86.0	1,325.4	100.0%
Percent of Total	29.0%	21.4%	12.6%	30.5%	6.5%	100.0%	

*Houston Area includes the developed areas within the 8-County region.
Source: S.L. Rose, H. Akbari, and H. Taha, 2003.

Reflective roofing installed on a University of Texas Health Science Center building in Houston.

various manufacturers that can be installed in various configurations to create a cool roof.

Reflective Roof Surfacing

The color of a roofing surface has a profound effect on the temperature it will reach while exposed to solar radiation. Solar energy reaches the earth as ultraviolet rays (3%), visible light (40%), and infrared energy (57%). *Solar reflectance* is defined as the percentage of solar energy that is reflected by a surface. This value is often referred to as Solar Reflectance Index (SRI) or *albedo*. The coolest materials have a high reflectance across the entire solar spectrum, primarily for the visible and infrared wavelengths. Most people understand that lighter colored surfaces have better reflectance characteristics than darker colored surfaces. However recent technologies allow darker colored surfaces to have higher levels of reflectance by reflecting more of the infrared (invisible) part of the spectrum.

Solar energy that is not reflected is absorbed by the roofing material and converted to heat, leading to heat build-up. The degree of heat build-up is dependent on the ability of the material to dissipate the heat. The dissipation of heat occurs by three methods: *conduction*, *convection*, and *radiation*. *Conduction* is the movement of heat through the body of the material from a high temperature, such as from the roof surface (high temperature) through the roof assembly/deck to the support structure (lower temperature). *Convection* occurs through the transfer of heat to its surroundings, such as the air. *Radiation* is the emission of energy away from the higher temperature material. The higher the *emissivity* of a material, the more quickly an object will radiate its absorbed energy.

A roofing material that is classified as a *cool roofing product* should have both a high solar reflectance value and a high emissivity value. Thus, it readily reflects solar radiation, absorbing very little energy, while it readily emits any heat energy that is absorbed. The result is a cooler roof surface that transmits less energy to the structure beneath it.

Photo courtesy of HydraTech

A green roof on the Baylor Research Institute in the Texas Medical Center provides intensive planting on top of this large structure.

Green/Garden Roofs

Green roofs or *Garden roofs* incorporate vegetation and growing medium with the roof assembly. This type of assembly utilizes a conventional roof membrane that is typically installed at the roof deck level and then insulation (optional), a drainage medium, a growing medium, and vegetation are placed over the roof membrane. The materials that are placed on top of the roof membrane not only isolate the membrane from the effects of exposure to solar energy, but also promote cooler temperatures through shading and *evapotranspiration* from the green roof infrastructure. *Evapotranspiration* is the process by which plants shed water, cooling their leaves through this evaporative effect. The moisture in the growing medium also evaporates, providing a cooling effect.

Roof Slope Definitions

Roofs with slope of 2/12 and less are considered to be *low-slope* roof applications. Roofs with slopes of greater than 2/12 are considered to be *steep-slope* roof applications.

Types of Cool Roofing Technologies

Roofing is made of many different materials and many of these materials are used for cool roofing products, depending on their reflectivity and emissivity. The major roofing materials are shown in Table 7.

The following are five types of cool roofing technologies and their major features. Most of these products are used for both new construction and reroofing.

Table 7
Typical Roofing Materials

Built Up Roof (BUR)—asphalt
BUR—coal tar
BUR—cold process
EPDM
CSPE/Hypalon®
PVC
TPO
Protected Membrane Roof
Other single plies
Spray polyurethane foam
Liquid-applied
Metal—structural
Metal—architectural
APP-modified bitumen
SBS-modified bitumen
Clay tile
Concrete tile
Fiberglass asphalt shingles
Organic asphalt shingles
Fiber-cement shingles
Wood shingles/shakes
Slate

Liquid-Applied Coatings

Liquid coatings can be applied to the top surface of the roof covering/membrane. These coatings are an acrylic polymer technology and are usually white in color. The color is achieved by adding a white pigment such as titanium dioxide or zinc oxide. White colored coatings typically have initial solar reflectance values of 75 to 80% and emissivity values of 0.90. The coatings can also be tinted to achieve various colors, generally lowering their solar reflectance values to 25 to 65%. Other coating options include aluminum-pigmented asphalt based coatings that have solar reflectance values of approximately 50% and emissivity values of 0.40.

Liquid coatings are typically applied directly to the prepared surface of the membrane at approximately 15-20 mil thicknesses (mil=thousandth of an inch). The acrylic-based coatings can be applied to the surface on both low-slope and steep-slope applications on virtually any roof material – built-up roofs, spray-applied polyurethane foam, modified bitumen, metal, and single-ply – to achieve the increased solar reflectance and emissivity values.

Prefabricated Membranes

Manufactured membranes are produced in various sheet widths and installed using various methods and configurations. Cool roofing *single-ply* membranes are commonly based on Polyvinyl Chloride (PVC), Copolymer Alloys, or Thermoplastic PolyOlefin (TPO) technology. The membranes are white or opaque in color, are reinforced with a fabric, 45 to 80 mil in thickness, and are either mechanically attached or fully adhered to the substrate. Cool roofing single-ply membranes can have high reflectance values of 75 to 85% at the time of installation and high emissivity values (0.80).

Modified bitumen membranes are prefabricated sheets composed of rubberized/plasticized asphalt with a reinforcing fabric and a factory-applied reflective surfacing that includes metallic foils, mineral granules, and proprietary materials. The lightest colored mineral granule surfacing

Maintenance Is Essential for Reflective Roofing

Maintaining the surface characteristic of the cool roof assembly is crucial for retaining the high reflectivity of the roof surface. Initial reflectivity is expected to decrease over time.

Surface contamination from air pollution, weathering, and biological growth reduces the albedo of reflective roofing, particularly in an area like Houston. Rain and periodic washing are necessary to restore reflectivity of a weathered surface.

EnergyStar® and other reflective roofing standards recognize that this is a characteristic of these roofing products. Energy savings calculations shown in this plan include this weathering characteristic. However, without proper maintenance that is specified for a roofing product, the energy saving benefits will likely be reduced.

Cool Roof Criteria

Solar Reflectance and Emissivity

Several entities have set forth criteria for both Solar Reflectance and Emissivity. These include the following:

- **EnergyStar®**: EPA's *Energy Star® program* has established an Initial Solar Reflectance for low-slope roofing of 65% and steep-slope roofing as 25% and an aged (3-year) SRI for low-slope roofing of 50% and steep-slope roofing of 15%.
  Website: http://208.254.22.6/index.cfm?c=roof_prods.pr_roof_products
- **ASHRAE 90.1** *ASHRAE 90.1* has established a Solar Reflectance Index of 70% and Emissivity of 0.75.
  Website: http://www.energycodes.gov/comcheck/89_compliance_manual.stm
- **Georgia White Roof Legislation:** The *Georgia White Roof Amendment* has adopted the criteria established by ASHRAE 90.1. *Cool Communities* program in Atlanta.
  Website: http://www.coolcommunities.org
- **Cool Roof Program:** The State of California has developed a *Cool Roofs Program* with established criteria of Initial Solar Reflectance and Emittance for Low-slope roofing of 65% or greater and 0.80 or greater, respectively; or a Minimum SRI of 75% using ASTM 1980. Steep-roof criteria to meet EPA Energy Star and high-profiled tiles to have initial reflectance of 40% or greater and emittance of 0.80 or greater; or a minimum SRI of 41% using ASTM 1980.
  Website: http://www.consumerenergycenter.org/coolroof
- **LEED Program:** U.S. Green Building Council's *Leadership in Energy & Environmental Design (LEED)* program offers credits in the category "Landscape & Exterior Design to Reduce Heat Islands/Roof" (credit 7). One credit point is achievable if the building uses a roof with both high solar reflectance and high emissivity. The requirement states: "Use Energy Star Roof-compliant, high-reflectance and high emissivity roofing (initial reflectance of at least 0.65 and three year aged reflectance of at least 0.50 when tested in accordance with ASTM E 903 and emissivity of at least 0.90 when tested in accordance with ASTM E 408) for a minimum of 75% of the roof surface; OR, install a green roof for at least 50% of the roof area."
  Website: http://www.usgbc.org/LEED/LEED_main.asp

has solar reflectance values on the order of 25%. The metallic foil-faced products have high reflectance values of 85% (aluminum & white colored) and high emissivity values (0.80) for the white colored foils. These membranes are traditionally installed on low-slope roof applications, but can also be installed on steep-roof applications such as dome and barrel-shaped structures.

Metal Panel Roof Systems

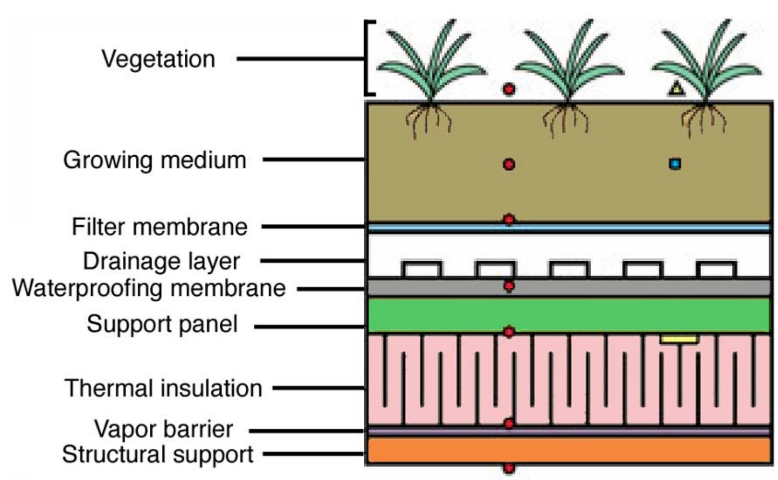
Metal roof systems include prefabricated panels that are manufactured in a variety of dimensions, profiles, and finishes and can be installed in a variety of configurations. Metal panels can have a baked on pre-painted finish that is white to meet the solar reflectance and emissivity criteria. However, technology is being utilized with infrared reflecting pigments in the paint finish where colored metal panels can meet these higher performance values. These types of roof systems are typically utilized in steep-slope roof applications, but could also be installed on slopes that are in the "low-slope" range. Total solar reflectance values can range from 15% to 70% through the use of appropriate colors and/or pigment technologies.

Specialty Products

Several products are available for steep-slope roof applications that can provide cool roof options including tiles and other prefabricated products. Clay and concrete tiles with various finishes can provide solar reflectance values of 40% and greater and emissivity values of 0.85 and greater. Other products such as coated metallic shingles can also meet reflectance and emissivity criteria.

Green Roof Systems

The green roof assembly typically includes a waterproofing/roofing membrane, drainage medium, filtration medium, insulation medium, growing medium, and vegetation. The *waterproofing/roofing membrane* can be one of many products: liquid-applied polymeric rubber, hot-applied



rubberized asphalt, prefabricated single-ply membrane, or multi-ply modified bitumen membrane. The *drainage medium* can include traditional granular fill material or prefabricated polymeric drainage panels with a filter fabric. A *root barrier/protection layer* can also be incorporated at this level. The insulation will typically include extruded polystyrene insulation when installed above the membrane. *Drainage mats, aeration products, and water retention mediums* can be incorporated into the assembly at this level.

The *growing medium* may include traditional landscaping type of soils or consist of lightweight engineered growing mediums. The vegetation can range from simple grasses to more complex shrubbery and tree plantings. Two common green roof designations are *Extensive* and *Intensive*. Extensive systems typically involve grasses or other natural self-propagating vegetation that requires very little if any irrigation and maintenance. These are installed over a relatively thin soil layer (4-6 inches). *Extensive* systems can be installed on slopes ranging from completely flat to 4/12 (4" of slope for every 12" of length). Intensive systems typically have a deep soil layer (6-24 inches), a large variety of vegetation, shrubbery, and trees that require

Table 8
Key Cool Roofing Technologies

Cool Roofing Technology	Uses	Solar Reflectance	Emissivity	Installed Cost*	Lifecycle
Liquid Applied Coatings					
White	Coating	75-80%	0.87	$1.25 - $1.50	5-10 years
Colors	Coating	25-65%	0.87	$1.25 - $1.50	5-10 years
Aluminum-asphalt	Coating	50%	0.40	$0.50 - $0.75	5-10 years
Prefabricated Membranes					
Single-ply (white)	New construction/ Reroofing	75-80%	0.80	$1.65 - $1.85	8-15 years
Modified bitumen	New construction/	25%		$1.50 - $1.80	15-20 years
Metallic foil/white	Reroofing	85%	0.80		
Metal Panel Roof Systems					
Metal Panel System (white)	New construction/ Reroofing	50%	0.60	$4.50 - $7.00	15-25 years
Green Roof/Garden Roof Systems					
Green Roof System	New construction/ Reroofing	N/A	N/A	$15.00 - $25.00	15-25 years
Specialty Products Systems					
Clay tiles (white)	New construction	40%	0.85	$6.00 - $8.00	20-30 years
Concrete tile (white)	New construction	40%	0.85	$6.00 - $8.00	20 years
Metallic tile (white)	New construction	40%	0.65	$5.00 - $7.00	20 years

* Costs for roofing and reroofing are highly variable due to different building characteristics and features. The cost ranges shown here are intended to be representational only to give an order of magnitude perspective of these costs. They reflect cost experience for roofing in the Houston region.

irrigation and regular maintenance. Intensive systems are traditionally installed on low slope roofs. In the U.S., they are often plazas or rooftops that offer a parklike setting for active use.

Benefits of Cool Roofing

Cool roofing not only reduces urban temperatures, but can pay for itself through energy savings and possible reduced maintenance costs for air conditioning equipment. For building owners, whether they are public buildings supported by taxpayers or commercial buildings serving the region's busineeses, these savings provide benefits to all of us by adding income to the region's economy. The benefits of cool roofing are described in more detail below.

Table 10
Houston Area Energy Use and Savings
(in GWh - GigaWatt hours)

	Office Buildings	Retail Buildings	Total
Base Case Use (without trees or cool roofing)	912	1,445	2,357
Projected Savings			
Trees Shading Bldg	21	49	70
Cool Roofing	**41**	**90**	**131**
Indirect	24	28	52
Total Energy Savings	86	167	253
% Savings	9.4%	11.6%	10.7%

Source: S. Konopacki and H. Akbari, 2002.
Note: Trees placed to shade the sides of building and indirect savings from cooler temperatures around buildings.
Note: The savings of 253 GWh is equal to the electricity from a large power plant (1 GW) operating at maximum output for 10.5 days.

Energy Savings for Building Owners

A reduction in the roof-top temperature has the direct effect of significantly reducing the electric bill of most buildings. Research studies of individual buildings by Lawrence Berkeley National Laboratory, Florida Solar Energy Center, and others have shown that savings on the order of 20% to 30% are usually achieved with a cool roof surface. Other studies have shown that a simple temperature reduction on the order of 3° to 7° F can result in a 10% reduction in air conditioning requirements. Energy for cooling buildings accounts for 11% of the electricity consumed in the United States, and in the Houston area, because of the climate, these percentages are even higher. Energy savings in the Houston area from the use of cool roofs on office and retail buildings alone would save an estimated $9 to $18 million annually, money that could be invested in ways other than wasted energy from hot roof surfaces.[14]

Reducing Peak Power Demand

Another crucial benefit that everyone receives from cool roofing is the reduction in the peak power demand needed to cool buildings during the hottest parts of the day. Power shortages and "brownouts" that can occur during these high demand periods stress our electric power systems and drive up energy costs, which in a deregulated electricity market are priced higher during these periods. Cool roofs are one way of "shaving" this peak through reduced demand at the very time demand is the highest. This also helps to avoid building excess power generation capacity, saving consumers money and avoiding new air pollution sources. Peak power reductions for the Houston area are estimated to be 1.3% of peak energy use from cool roofing on office and retail space alone.[15]

[14] S. Konopacki and H. Akbari, *Energy Savings for Heat Island Reduction Strategies in Chicago and Houston*, Lawrence Berkeley National Laboratory, p. 33, office and retail buildings direct albedo; energy savings from reflective roofing of 10% = $9 million; February 2002. Projected energy savings of 20% = $18 million.
[15] ibid, p. 33, February 2002.

Improved Building Comfort

One of the extra benefits of cool roofs is the added comfort for building occupants. This is important for customers using these buildings and it adds to worker productivity by improving employee comfort, including unairconditioned buildings such as warehouses and older, poorly insulated buildings. Reducing the rooftop temperature reduces the fluctuations in interior temperatures that causes discomfort. In some buildings, the air conditioning system simply can't keep up with very high outdoor temperatures. When this happens, although air conditioning is operating, the interior temperature may continue to rise. Customers and occupants experience this as discomfort.

Cooler Temperatures Around the Building

With cooler temperatures on the rooftop, the temperatures of areas surrounding the building can actually decrease, particularly when coupled with more trees and use of reflective or porous paving. The heat absorbed by roof tops raises temperatures to 160º F or more and heats up the immediate surrounding area. Each building acts as its own mini-heat island in this respect. Since cool roof surfaces are closer to ambient air temperatures, they don't heat surrounding air as much. Green or garden roofs cool roof-top air by using a portion of the sun's energy to evaporate the available moisture. The sun's energy is also used by vegetation for photosynthesis and other plant processes.

Improved Efficiency of HVAC Equipment

A reduction in the cooling demand of a building reduces the actual time that HVAC equipment operates. This not only reduces energy costs, but is expected to increase the service life of the equipment. Reduced operation time may also reduce on-going maintenance and repair costs of this equipment. Studies are needed to quantify these effects so that any additional cost savings can be verified.

Extended Roof Life Cycle

Solar radiation and high temperatures are the enemies of most roofing materials. They cause them to degrade over time and eventually fail. By lowering the surface temperatures, roofing may last considerably longer. This added length of life would delay eventual roof removal by several years and thereby delay the addition of roof waste to landfills where they comprise a significant part of the waste stream.

With green roofs, the roof assembly increases the service life of the waterproofing/roofing membrane. The waterproofing/roofing membrane is isolated from the weathering elements and exposure to UV radiation, consequently the membrane is maintained at a relatively constant and moderate temperature which results in a longer service life.

Testing Procedures for Solar Reflectance, Emissivity and Cool Roofing

Standardized test methods exist for determining the *solar reflectance* and *emittance* of a product/assembly. The test methods for solar reflectance are as follows: ASTM E 903, ASTM E 1175, and ASTM E 1918 are Standard Test Methods for measuring solar reflectance.

ASTM 1918 measures the reflectivity of larger surfaces, such as roofs, in the field. ASTM E 408, ASTM C 835, and ASTM C 1371 are standard test methods for measuring thermal emissivity. ASTM 1980 is the standard for calculating the solar reflectance index.

Cool Roof Rating Council

The *Cool Roof Rating Council* (CRRC) has developed protocols and procedures for testing of products for Solar Reflectance and Emissivity. The CRRC is also established as a *library* for maintaining the various test results performed by CRRC accredited laboratories on the various products submitted by manufacturers.

The Cool Roof Rating Council (CRRC) is an independent and unbiased organization that has established a system for providing Building Code Bodies, Energy Service Providers, Architects & Specifiers, Property Owners and Community Planners with accurate radiative property data on roof surfaces that may improve the energy efficiency of buildings while positively impacting our environment.

See http://coolroofs.org

Cool Roof Energy Savings Calculator

Oakridge National Laboratory has developed an easy to use on-line energy calculator for flat roofs that estimates energy savings from the use of reflective roofing. It provides estimates for specific cities and regions, such as Houston.

http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm

Photo courtesy of HydrTech

The South Texas Law School garden roof provides greenspace for employees and students as well as cooling this part of the roof structure.

Water Benefits of Green Roofs

Green roofs are cooler, but also provide several water-related benefits. They reduce water runoff, improve the water quality of runoff, and reduce potential flooding risks. The green roof components collect and retain a part of what would otherwise be roof-top runoff. In addition, the structure of a green roof assembly slows the water runoff as the water migrates through the multiple layers. The reduction of the amount and rate of runoff can eliminate, reduce, or minimize runoff controls (i.e. retention ponds and pipe sizes) that may be otherwise required. Studies show that a relatively dry soil layer, 4-inch thick, can absorb a full inch of rainfall before runoff occurs.

At the same time, the quality of the water draining from a green roof is cleaner. As runoff migrates through the components of a green roof assembly, impurities within the water are retained by the soil and other retention devices within the assembly. Microorganisms in the growing medium can breakdown many types of pollutants while other pollutants, such as heavy metals, will bind to soil particles

Green roof assemblies can be constructed with specific components to retain and store quantities of roof-top runoff. The collected runoff is being utilized in some applications for other uses such as irrigation of roof-top vegetation or other surrounding landscaping.

Green Roof Amenties

Green roofs can be constructed to provide walking/sitting areas for building occupants, additional usable building space at the roof elevation, a desirable building feature for current tenants, or improved marketability of the property for potential sale. In highrise locations, green roofs are built so that occupants can see them from above and use them as visual greenspace.

New technologies like these photovoltaic (PV) shingles allow rooftops to generate their own electricity.

Development of More Sustainable Roofing Technologies

Roofing products are continuously improved, many aimed at achieving energy savings and lowering environmental impacts. Changes in color chemistry and roofing materials provide more reflective roofing that is available in darker colors. Photovoltaic systems are being integrated into roofing structures and materials. Adhesives are being used that emit much lower levels of volatile organic compounds (VOCs). Some new roofing materials are taking advantage of the use of recycled materials, and some old roofing materials that would have gone to a landfill are being reused in paving materials.

Cool Roofing Plan Components

The following plan components set forth proposed actions and strategies for implementing cool roofing in the Houston region. They include six key components that utilize a combination of code and/or municipality requirements, monetary incentives, and education.

Houston's Cool Roofing Plan Does NOT Target Single-Family Residential Roofs

Many people who have reviewed this plan immediately think of the roof on their home. That's expected. However, this plan is NOT about those roofs. It is about buildings with "flat roofs." Almost all of these are commercial, office, retail, industrial or public buildings. A small percentage of residential structures (mostly apartments and other multi-family units) have flat roofs and these can are suitable for cool roofing technologies.

This does NOT mean that there aren't cool roof technologies suitable for sloped roofs and single family residences. Coated architectural metal roofs, various types of tiles, and even some single-ply cool roofing technologies are attractive options for sloped roofs. However, these applications are not targeted. The plan is intended to affect the greatest amount of roofing in the Houston area, not these more limited applications.

As more cool residential roofing technologies become available, they should be incorporated.

Roofing in the Houston area

Roofing surfaces account for roughly one-fifth of Houston's developed area, amounting to 284 square miles (Table 10). The largest portion, well over half, consists of residential roofing. The two major categories of roofing that affect the use of cool roofing technologies are *sloped roofing*, such as that found on most homes, and *flat roofs*, also called *low slope roofs*. Table 11 illustrates the types of buildings most suited to current cool roofing technologies. These are primarily commercial, retail, public and office buildings, but include some multi-family residential units.

Because of the availability of suitable roofing technologies and associated energy savings, *the best opportunities for cool roofing in the Houston region are low-slope roofs.* Therefore, the plan targets all low-slope roofs. There are already millions of square feet of reflective roofing installed in the Houston region on commercial and public buildings. Roofing companies experienced in these products and installation are available. Table 11 also shows that low-slope roofing is found primarily on commercial buildings such as office and retail structures, aand on many public buildings such as schools, libraries, and governmental offices. In addition, an estimated 5 to 10% of the residential structures in the Houston area have low-slope roofs that are suited to cool roofing technologies. Most of these are apartment or multi-family buildings. As cool roofing products become more available for sloped roofs, the plan can be changed to include them.

This plan is NOT about conventional residential roofs. It targets buildings with "flat roofs" where cool roofing technologies can be applied.

Although the life of roofing can range from 10 to over 30 years, in practice most low slope roofs are replaced or significantly repaired within 10 years. In the Houston region, heat and weather-related damage can shorten the life of many roofing materials. This means that over this period of time, most of the suitable roofs could take advantage of cool roofing's benefits. This would occur as a part of routine replacement, repairs, and reroofing. In addition, new buildings added to the inventory could utilize cool roofing. With the plan components set forth below, *it is expected that within 10 years one-half or more of all low-slope roofs in the region would be cool roofing. This*

Table 11
10-Year Projection of Changes in Cool Roofing in the Houston Region
in millions of square feet

Land Use/Land Cover	Projected Roof Area	% of All Roof Area	Current Albedo	Targeted Roof Area*	New Albedo**
Residential	5,189	53.7	0.15	519	0.65
Commercial/Service	669	6.9	0.20	536	0.70
Industrial	642	6.6	0.20	514	0.70
Transportation/ Communications	136	1.4	0.20	109	0.70
Industrial and Commercial	571	5.9	0.20	457	0.70
Mixed Urban or Built-Up Land	394	4.1	0.20	315	0.70
Other Mixed Urban or Built-Up Land	2,056	21.3	0.20	1,645	0.70
Total	9,657	100.0%	0.17 avg	4,094	0.36

Source of Roof Area and Current Albedo: S.L. Rose, H. Akbari, and H. Taha, 2003.
* *Targeted Roof Area* includes 10% of existing and future residental buildings with low slope roofs and 80% of all existing and future commercial, office, and public buildings over the next 10 years.
** *New Albedo* is an increase of 0.50 for the albedo for all targeted roof areas. The bottom number (0.36) is the projected overall albedo average for roofing, more than doubling current average albedo levels.

Table 13
Plan Targets by Type of Building and Roof

Legend:
- Building and roof types best suited to current cool roofing technologies
- Primary Plan Target
- Secondary Target

Type of Building	Low Slope/Flat Roofs	Sloped Roofs
Commercial/Retail Office Buildings Industrial Buildings Public Buildings	Most Buildings	Some Buildings
Multi-Family Residential Units	Many Buildings	Most Buildings
Single Family Residential	A Few Residences	Most Residences

Cool Roof Plan Components

1. Economic Incentives for Cool Roofing
2. Municipal Codes
3. Widespread Use of Energy Code Provisions
4. Creating Visible Public Partnerships and Leadership
5. Providing Information on Cool Roofing
6. Increasing Public Awareness

would increase average roofing albedo by almost 70%.

As Table 11 shows, 80% of all existing and future non-residential roofing is targeted for cool roofing applications. Over a ten-year period, the albedo of these roofs can be increased from an estimated current average value of 0.20 to a target value of 0.70. In addition, all low slope residential roofing (primarily apartments and multi-family units) will be targeted for cool roofing. Albedo levels using current technologies would increase from 0.15 to 0.65.

As new buildings are built and as old roofing is replaced, cool roofing technologies will be encouraged. In addition, other buildings with low-slope roofs, such as some residential structures, will be encouraged to use cool roofing. Public agencies, school districts and governments will be encouraged to set the example on their buildings.

Economic Incentives for Cool Roofing

Providing economic incentives to the end user is an effective way to promote the use of cool roofing technologies. A program is proposed that would offer qualifying participants a "rebate/reward" based on the amount of installed roof area. An example of such a program has been implemented by the State of California that offers incentives that range from 15¢ to 25¢ per square foot of roofing for the installation of reflective roofing materials. California undertook this program because of the energy savings from cool roofing. Installation of 60 million square feet saves 20 megwatts of electricity during peak demand. *Austin Energy* provides a rebate of 10¢ per square foot for installation of reflective roofing.

Texas might offer such rebates directly as part of a state energy program, through local property tax reductions providing an immediate incentive to building owners for installing cool roofs, and/or through utilities. Local taxing jurisdictions could be reimbursed by the State for these reductions.

Municipal Codes

Incorporating requirements for the implementation of cool roofing in municipal codes is an effective method to meet plan goals. However, changes in building codes require considerable time, effort, and support from community leaders. In addition, it is crucial to have the support of stakeholders in the building trades and the business community. Such changes should only be considered after there is sufficient understanding and support among Houston communities, leaders and stakeholders.

Widespread Use of Energy Code Provisions: ASHRAE 90.1

The *Energy Standard for Buildings, Except Low-Rise Residential Buildings* in the Texas energy code allows for the reduction of insulation within the roof assembly for a cool roof. The roof surface must have at least a total Solar Reflectance Index (SRI) of 70% and thermal emittance value of 0.75. Typical reductions of 14% to 23% in the insulation can be realized (depending on the location of the facility within the State). Using cool roofing technologies that cost little or no more than other roofing products can produce immediate savings in building construction costs (as well as saving money on future energy consumption). Builders, architects, engineers, developers and building owners should be encouraged to take advantage of the cool roof provision in the energy code.

Creating Visible Public Partnerships and Leadership

Public agencies such as school districts, local governments, community colleges, public universities, and hospitals are building owners that can take advantage of cool roof benefits while setting a leadership example for other

Existing Economic Incentives for Cool Roofing

Economic incentives that are currently available include the *standard offer program* from public utilities, a Public Utility Commission grant program, and low-interest LoanStar loans.

The *standard offer program* required of utilities can provide payments for energy savings from building improvements, such as cool roofing. It is currently available, but largely unknown and unused for cool roofing applications.

The Texas Public Utility Commission has a small grant program that has been used in Austin for cool roofing.

Low interest loans (3%) from the LoanStar program managed by the State Energy Conservation Office (SECO) are available to public entities for cool roofing.

While these funding sources are relatively small compared with the number of cool roofing applications needed, they are currently available to building owners.

Development Code Incentives–FAR

The City of Portland has implemented a Floor Area Ratio (FAR) bonus option to encourage green roof development for the purposes of water runoff control. An FAR bonus allows the total area of building to be larger than it might be otherwise if certain criteria are met. These criteria are:

1) If the total area of the green roof is 10% to 30% of the building's footprint, each square foot of green roof earns one square foot of additional floor space.
2) If the total area of the green roof is from 30% to 60% of the building's footprint, each square foot of green roof earns two square feet of additional floor space.
3) If the total area of the green roof is 60% or more of the building's footprint, each square foot of green roof earns three square feet of additional floor space.

Example: If the building footprint of a 6-story, 12,000 square foot building is 2,000 square feet and the green roof is 1,600 square feet, then the builder would be allowed to increase the total size of the building by 4,800 square feet (3 x 1,600), increasing the building from 12,000 square feet to 16,800 square feet. The footprint of the building would not be increased.

First Steps Towards Implementation

- Form a *Cool Roofing Steering Committee* of various agencies and stakeholders to oversee the implementation of heat island mitigation measures for cool roofing actions.
- Work with the City of Houston to set goals and implement cool roofing projects, including the identification of cool roofing opportunities in city owned buildings. Similar actions are needed with school districts, school buildings, and other local governments.
- Work with the Texas Commission on Environmental Quality (TCEQ) to develop a strategy for including cool roofing in the State's air quality plan.
- Work with appropriate officials to ensure that the state energy code includes explicit provisions for reflective roofing and green roofing technologies.
- With the TCEQ and EPA, develop specific, creditable methods of mitigating the heat island effect to help ensure compliance with the Clean Air Act and Clean Water Act.
- Work the Houston-Galveston Area Council, planning organizations, and cities within the eight-county region to incorporate heat island mitigation measures such as cool roofing into community planning and development activities.
- Establish a roofing baseline for measuring progress in achieving cool roofing goals, which helps establish a potential means of verifying air quality credit.
- Work with the Steering Committee to design and launch a cool roofing education, training and outreach program for state and local agencies, buildings owners, building managers, and roofing industry companies and organizations.

building owners. The *City of Houston* and *The University of Texas Health Science Center–Houston* are already demonstrating their interest by installing cool roofs. This plan proposes to expand both the number of buildings and the visibility of these buildings to demonstrate to other building owners the availability and utility of cool roofs. Public officials will be asked to play a leadership role in letting others know of this experience. *Leading by example* also lets the general public become more aware and willing to participate.

Providing Information to Building Owners and Managers

The key decision makers on roofing choices for existing buildings are building owners and managers. To impact these decisions, independent consultants and roofing specialists could develop local protocols and guidelines for the implementation of cool roofing technologies. These would provide building owners and managers with independent information that they could utilize for decisions on their buildings and properties. The guidelines would include common practices, commercially available materials/suppliers, and technical support for the installation of cool roof options.

The other partners in roofing and reroofing decisions are often roofing companies. Parallel efforts are needed to ensure that these companies are aware of cool roofing technologies and benefits. In addition to written materials, workshops aimed at building owners, managers, and roofing companies are needed. These would be implemented through appropriate professional and business organizations.

Increasing Public Awareness

To change current practices over the next 10 years requires public awareness of why these changes are needed, particularly where governmental expenditures are involved. This applies to other heat island initiatives as well. To increase public awareness, it is proposed that information on cool roofing technologies be published illustrating current cool roof projects in Houston, and their track record. It will be important to include documented benefits of such projects. Currently little documented information has been published, unlike California where numerous buildings have been tested.

Other strategies to increase public awareness include brief, written materials, videos, and seminars. These should provide consistent, well documented information that demonstrates cool roofing technologies and benefits (as well as other aspects of urban heat island mitigation).